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TECHNICAL MANUSCRIPT 402

PHOTOCONTROL OF ETHYLENE PRODUCTION BY LETTUCE SEEDS AND BEAN HYPOCOTYLS

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DEPARTMENT OF THE ARMY
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ABSTRACT

Red light of about 660 mμ has been shown to promote the germination of *Lactuca sativa* var. Grand Rapids seeds and to cause the unfolding of the hypocotyl hook of *Phaseolus vulgaris* L. var. Black Valentine. In both cases, the effect of red light was reversed by far-red light at about 730 mμ.

Ethylene promoted the germination of lettuce seeds and caused a negative curvature of bean hooks. Red light stimulated ethylene production from lettuce seeds but it inhibited ethylene production from the bean hooks. Lettuce seed germination and bean hook unfolding seem to be examples in which phytochrome promotes or inhibits the formation of ethylene that, in turn, appears to control the physiological response.

I. INTRODUCTION

Physiological processes in plants influenced by ethylene include abscission, dormancy, epinasty, flowering, fruit ripening, growth inhibition, membrane permeability, root initiation, and swelling. Burg[1] has reviewed these and other effects of the gas. Occasionally these processes are also influenced by other growth regulators, and evidence is rapidly accumulating that some of the effects of indoleacetic acid,[2-8] herbicides,[9-12] gibberellin,[2] and abscisin II[2] are mediated through ethylene.

This paper presents evidence that ethylene production is under photocontrol and that some of the effects of light on plants may be mediated through ethylene.

II. MATERIALS AND METHODS

Seeds of Lactuca sativa var. Grand Rapids were germinated in gas-collection bottles described previously[4] containing 10 ml of 1.5% agar. Each bottle contained 110 mg of seeds (about 100). During the 16-hour imbibition period, the seeds were exposed to far-red light.

Seedlings of Phaseolus vulgaris var. Black Valentine were grown in the dark in vermiculite for 6 to 7 days. Methods for harvesting, handling, and determining the hook opening followed those described by Klein et al.[13] Ten hypocotyl hooks were set, base down, in 10 ml of 1.5% agar in 125-ml Erlenmeyer flasks sealed with rubber vaccine caps.

Far-red light was provided by a 150-watt incandescent bulb and was filtered by a Corning 165-mm square filter (Glass No. 2600 CS 7-69). For red light, the filter was a far-red Corning filter (Glass No. 3961 CS 1-56). Except for exposure to red or far-red light, all manipulations were performed under a green light (Corning filter CS 5-75) that had no effect on seed germination or hook opening. A temperature of 24±2 C was maintained during the experiments.

Levels of ethylene surrounding the experimental material were determined by gas chromatography.[4]

III. RESULTS

The effect of light on hook opening is shown in Table 1. Hooks were excised from 6- to 7-day-old bean seedlings, placed on moist paper toweling to permit the escape of ethylene from wounded sections, then placed base down in agar and given light treatments (Table 1). The position of the bottles was shifted hourly during the light exposure so that incident energy was distributed as uniformly as possible. As observed earlier by others,[13] the hook opening was stimulated by red light and inhibited by far-red light. Red light inhibited ethylene production from the hypocotyl sections and far-red light stimulated ethylene production. Data in the column headed △ Curvature are the final curvature minus the initial curvature as determined by the methods of Klein et al.[13] A positive value indicates that the hook opened and a negative value indicates that the hook closed. Addition of 1 ppm ethylene to the gas phase surrounding the hooks resulted in a △ curvature of -40 degrees even in the presence of red light.

TABLE 1. EFFECT OF LIGHT ON HOOK OPENING OF BLACK VALENTINE BEANS

Treatment		△ Curvature, a/	C_2H_4 in Gas Phase, ppm	
0 to 5 hours	5 to 10 hours	degrees	0 to 12 hours	12 to 18 hours
dark	dark	-11	0.48	0.12
red	dark	+20	0.36	0.11
red	red	+46	0.38	0.07
red	far-red	-16	0.55	0.14
dark	far-red	-12	0.59	0.18

a. Initial curvatures of the hooks average 15 degrees. Final curvatures measured 31 hours after they were excised from the seedling.

The effect of red and far-red light on ethylene evolution and germination of lettuce seeds is shown in Table 2. In this experiment seeds were allowed to imbibe water for 16 hours in the presence of the far-red light source. The bottles were placed 10 to 16 cm from the incandescent light bulb and a fan was placed nearby to reduce the effects of heating. After that time, the bottles were placed either in the dark or given the treatments indicated. Germination and accumulation of ethylene in the gas phase was measured 24 hours later. As shown in Table 2, 1 hour of red light after the 16-hour imbibition period in far-red light stimulated ethylene production. This stimulation was blocked by a terminal far-red exposure and enhanced by a terminal red exposure. Table 2 also shows that ethylene stimulated the germination of seeds receiving both red and far-red light treatments.

TABLE 2. EFFECT OF LIGHT ON ETHYLENE EVOLUTION AND GERMINATION OF GRAND RAPIDS LETTUCE SEEDS

Treatment[a]	Germination, %	Ethylene in Gas Phase,[b] ppm
FR	50	1.1
FR-R	82	1.7
FR-R-FR	44	0.8
FR-R-FR-R	86	2.2
FR-R + 10 ppm ethylene	89	-
FR + 10 ppm ethylene	71	-

a. FR = dark; FR-R = 1-hour exposure to red light; FR-R-FR = additional 1-hour exposure to far-red light; FR-R-FR-R = additional 1-hour exposure to red light.

b. Bottles were sealed after the last light treatment, and ethylene was measured 24 hours later.

IV. DISCUSSION

Kang et al.[7] reported that red light inhibited the production of ethylene from bean hypocotyls and that ethylene stimulated hook closing. Our observations confirm this report and suggest that this is a true phytochrome effect because it was reversed by far-red light. Earlier, Goeschl and Pratt[14] reported that morphological responses to light, including the opening of the pea (Pisum sativum L. var. Alaska) hook, could be reversed by ethylene. It appears that in hook tissue, ethylene production is inhibited when phytochrome is in the far-red absorbing form and stimulated when it is in the red absorbing form.

The observation that ethylene promotes the germination of seeds has been reported earlier by a number of workers.[15-17] The observation reported here extends this effect of ethylene to another species. As shown in Table 2, a terminal germination-promoting red exposure stimulated ethylene production; a germination-inhibiting far-red exposure inhibited ethylene production. These results suggest that light may regulate ethylene evolution which, in turn, regulates germination.

The method through which phytochrome controls ethylene production is unknown. However, the observation that phytochrome does control ethylene production in bean seedlings and in lettuce seeds suggests possible explanations for other physiological processes. Red light stimulates the formation of pigments associated with ripening in tomato[18] and apple[19] skins. That ethylene does accelerate ripening has been well documented.[1] Red light during the long dark induction period inhibits the flowering of cocklebur (Xanthium pensylvanicum Walln.).[20] Recently, ethylene has been shown to have the same effect.[3]

The number of phytochrome-mediated processes that are mimicked by ethylene remains to be established, but it appears now that this simple hydrocarbon gas acts as an intermediate in some phytochrome-mediated processes as well as in some processes mediated by auxin, herbicide, gibberellin, and abscisin II.

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13. ABSTRACT

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14. Key Words
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